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METAL FUEL CELL SYSTEM FOR PROVIDING BACKUP POWER TO ONE OR MORE LOADS

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1. Field of the Invention.

This invention relates generally to uninterruptible power supplies for providing backup power to electrical equipment during power outages, and, more specifically, to uninterruptible power supply systems based on metal fuel cells.

2. Related Art.

A great deal of electronic equipment in the modern world relies upon high-quality, reliable electrical power. Such equipment, each a load, includes, for example and without limitation, telecommunications equipment, Internet servers, corporate mail servers, routers, power supplies, computers, test and industrial process control equipment, alarm and security equipment, many other types of electrical devices, equipment for which a power source is necessary or desirable to enable the equipment to function for its intended purpose, and the like, and suitable combinations of any two or more thereof. Over the past decade, as the digital age has taken hold, there has been an explosive growth in the deployment of such equipment.

For many applications of such equipment, power outages can lead to losses of data, equipment damage, missed deadlines, and/or lost productivity, and therefore must be avoided. At the same time, the reliability of the traditional power generation, transmission, and distribution network has fallen in some countries due in part to the increased demands which have been placed on this network throughout the world. The result is that uninterruptible power supplies (UPS) have emerged as a means for providing backup power to such equipment in the event of a power outage.

Traditionally, UPSs use lead-acid batteries as the energy source. Such UPSs typically provide up to about 20 minutes of backup power, which is usually enough time to allow users to shut down their equipment in an orderly fashion, but not enough time to

allow the equipment to operate through all power outages. Backup times much longer than this are usually not considered feasible as the required UPSs would be too heavy and bulky.

Hydrogen fuel cells have also been proposed as the energy source for a UPS. Compared to lead/acid batteries, hydrogen fuel cells are capable of providing backup power over longer time durations. However, hydrogen fuel cells are fueled with hydrogen, which is flammable, explosive, and requires high pressure to store. Consequently, the hydrogen fuel cell can be unsuitable for many office environments. For additional information on hydrogen fuel cells, the reader is referred to U.S. Patent Nos. 6,117,267; 5,980,726; 6,168,705; and 6,099,716; each of which is incorporated herein by this reference.

RELATED APPLICATION

This application is related to U.S. Patent Application Serial No. __/______, entitled "POWER SYSTEM INCLUDING HEAT REMOVAL UNIT FOR PROVIDING BACKUP POWER TO ONE OR MORE LOADS," Howrey Dkt. No. 04813.0016.NPUS00, filed concurrently herewith, and owned in common by the Assignee hereof, which is hereby fully incorporated by reference herein as though set forth in full.

SUMMARY

The invention provides a metal fuel cell system for providing backup power to one or more loads upon the occurrence of a power outage condition, defined to include a disruption or discontinuation in the delivery of primary power (i.e., power from a primary source, namely, a source other than the metal fuel cell system) to the one or more loads. The system comprises one or more metal fuel cells, each comprising a power source and a fuel storage unit, that deliver backup power to the one or more loads upon the occurrence of a power outage condition. Each metal fuel cell can optionally further comprise a reaction product storage unit to store the reaction products from the fuel cell, and/or a second reactant storage unit, and/or a regeneration unit to regenerate

the reactants of the fuel from the reaction products. The system further comprises a controller that, upon sensing the occurrence of a power outage condition, operatively engages the one or more metal fuel cells and/or engages a flow of the one or more second reactants at a time prior to in the range(s) from about 10 microseconds to about 10 seconds after the controller senses the occurrence of a power outage condition. Optionally, the controller can be configured to sense a cessation of the power outage condition and, responsive thereto, to engage the primary power to provide power to one or more of the regeneration units in the one or more fuel cells and/or to disengage the one or more fuel cells from providing power to the one or more loads. The system can also optionally further comprise a power conversion unit to convert to alternating current (AC), or to direct current (DC), the DC power output by the one or more metal fuel cells. In one implementation, the system of the invention further comprises means for supporting the one or more metal fuel cells, and at least one of the one or more loads. Optionally, the means for supporting can be configured to support one or more of the remainder of the one or more loads, the controller, and/or the optional power conversion stage.

The invention further provides a metal fuel cell system for providing backup power to one or more loads upon the occurrence of a power outage condition, wherein such system has one, or any suitable combination of two or more, of the following properties: the system can be configured to not utilize or produce significant quantities of flammable fuel or product, respectively; the system can provide backup power to the one or more loads for an amount of time limited only by the amount of fuel present (e.g., in the range(s) from about 0.01 hours to about 10,000 hours or more); the system can be configured to have an energy density in the range(s) from about 35 Watt-hours per kilogram of combined fuel and electrolyte added to about 400 Watt-hours per kilogram of combined fuel and electrolyte added; the system can further comprise an energy requirement, and can be configured such that the combined volume of fuel and electrolyte added to the system is in the range(s) from about 0.0028 L per Watt-hour of the system's energy requirement to about 0.025 L per Watt-hour of the system's energy requirement; the system can be configured to have a fuel storage unit that can store fuel

at an internal pressure in the range(s) from about – 5 pounds per square inch (psi) gauge pressure to about 200 psi gauge pressure; the system can be configured to hold a pre-charge of fuel in the power producing cell(s) of the power source of the metal fuel cell, optionally in an amount sufficient to permit operative engagement of the fuel cell(s) at a rate significantly faster than when no such fuel is present and/or sufficient to supply power for a time in the range(s) of about 0.001 minutes to about 100 minutes or more without additional fuel being added; and the system can be configured to expel substantially no reaction products outside of the system (e.g., into the environment).

In addition, the invention provides methods of providing backup power to one or more loads comprising, upon sensing an outage of primary power to the one or more loads, operatively engaging one or more metal fuel cells to provide power to the one or more loads. The invention also provides methods of pre-charging a fuel cell system for providing backup power to one or more loads comprising placing an amount of fuel in cell cavities of a power source of a fuel cell system prior to operative engagement of the fuel cell system. The invention further provides methods of utilizing a pre-charged fuel cell system for providing backup power to one or more loads, comprising operatively engaging a fuel cell system containing fuel in cell cavities of a power source of the fuel cell system prior to its operative engagement for a time in the range from about 0.001 minutes to about 100 minutes without adding additional fuel thereto.

Other systems, methods, features and advantages of the invention will be or will become apparent to one with skill in the art upon examination of the following figures and detailed description. It is intended that all such additional systems, methods, features and advantages be included within this description, be within the scope of the invention, and be protected by the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention. In the figures, like reference numerals designate corresponding parts throughout the different views.

FIG. 1 is a block diagram of a metal fuel cell.

FIG. 2 is a block diagram of a metal fuel cell system for providing backup power to one or more loads.

FIG. 3 is one implementation of the system of FIG. 2.

FIG. 4 is a flowchart of an embodiment of a method according to the invention.

DETAILED DESCRIPTION

Introduction to Metal Fuel Cells

A block diagram of an embodiment 100 of a metal fuel cell is illustrated in Figure 1. As illustrated, the fuel cell 100 comprises a power source 102, an optional reaction product storage unit 104, an optional regeneration unit 106, a fuel storage unit 108, and an optional second reactant storage unit 110.

The power source 102 in turn comprises one or more cells each having a cell body defining a cell cavity, with an anode and cathode situated in each cell cavity. The cells can be coupled in parallel or series. In one implementation, they are coupled in series to form a cell stack.

The anodes within the cell cavities in power source 102 comprise the fuel stored in fuel storage unit 108. The fuel is a metal that can be in a form to facilitate entry into the cell cavities. For example, the fuel can be in the form of metal (or metal-coated) particles or liquid born metal (or metal-coated) particles or suitable combinations thereof. Exemplary metals for the metal (or metal-coated) particles include without limitation zinc, aluminum, lithium, magnesium, iron, and the like. Within the cell cavities of power source 102, an electrochemical reaction takes place whereby the anode releases electrons, and forms one or more reaction products. When the fuel is optionally already present in the anode of the cell cavities in power source 102 prior to activating the fuel cell, the fuel cell is pre-charged, and can start-up significantly faster than when there is no fuel in the cell cavities and/or can run for a time in the range(s) from about 0.001 minutes to about 100 minutes or more without additional fuel being moved into

the cell cavities. The amount of time which the fuel cell can run on a pre-charge of fuel within the cell cavities can vary with, among other factors, the pressurization of the fuel within the cell cavities, and alternative embodiments of this aspect of the invention permit such amount of time to be in the range(s) from about 1 second to about 100 minutes or more, and in the range(s) from about 30 seconds to about 100 minutes or more.

The released electrons flow through a load to the cathode, where they react with one or more second reactants from the optional second reactant storage unit 110 or from some other source. Optionally, the second reactant can be present in the fuel cell and pre-pressurized to any pressure in the range(s) from about 0.01 psi gauge pressure to about 200 psi gauge pressure prior to the controller sensing the power outage condition to facilitate the fuel cell's start-up in a timeframe significantly faster than when there is no second reactant present and no pre-pressurization in the fuel cell prior to the controller sensing the power outage condition. Optionally, the one or more second reactants are present in the power source 102 at a time prior to an outage sense time, which outage sense time is in the range(s) from about 10 microseconds to about 10 seconds after the controller has sensed outage of primary power to the one or more loads system. Optionally, the time is also after the controller has sensed outage of primary power to the one or more loads. The flow of electrons through the load gives rise to a voltage for the cells. When the cells are combined in series, the sum of the voltages for the cells forms the output of the power source.

The one or more reaction products can then be provided to optional reaction product storage unit 104 or to some other destination. The one or more reaction products, from unit 104 or some other source, can then be provided to optional regeneration unit 106, which regenerates fuel and one or more of the second reactants from the one or more reaction products. The regenerated fuel can then be provided to fuel storage unit 108, and/or the regenerated one or more second reactants can then be provided to optional second reactant storage unit 110 or to some other destination. As an alternative to regenerating the fuel from the reaction product using the optional

regeneration unit 106, the fuel can be inserted into the system from an external source and the reaction product can be withdrawn from the system.

The optional reaction product storage unit 104 comprises a unit that can store the reaction product. Exemplary reaction product storage units include without limitation one or more tanks, one or more sponges, one or more containers, one or more vats, one or more barrels, one or more vessels, and the like, and suitable combinations of any two or more thereof. Optionally, the reaction product storage unit 104 (if present) is detachably attached to the system.

The optional regeneration unit 106 comprises a unit that can electrolyze the reaction product(s) back into fuel (e.g., metal particles and/or metal-coated particles) and/or second reactant (e.g., air, oxygen, hydrogen peroxide, other oxidizing agents, and the like, and suitable combinations of any two or more thereof). Exemplary regeneration units include without limitation metal (e.g., zinc) electrolyzers (which regenerate a fuel (e.g., zinc) and a second reactant (e.g., oxygen) by electrolyzing a reaction product (e.g., zinc oxide (ZnO)), and the like. Exemplary metal electrolyzers include without limitation fluidized bed electrolyzers, spouted bed electrolyzers, and the like, and suitable combinations of two or more thereof. The power source 102 can optionally function as the optional regeneration unit 106 when operated in reverse, thereby optionally foregoing the need for a regeneration unit 106 separate from the power source 102. Optionally, the regeneration unit 106 (if present) is detachably attached to the system.

The fuel storage unit 108 comprises a unit that can store the fuel (e.g., metal (or metal-coated) particles or liquid born metal (or metal-coated) particles or suitable combinations thereof). Exemplary fuel storage units include without limitation one or more tanks (for example, without limitation, a high-pressure tank for gaseous fuel (e.g., hydrogen gas), a cryogenic tank for liquid fuel which is a gas at operating temperature (e.g., room temperature) (e.g., liquid hydrogen), a metal-hydride-filled tank for holding hydrogen, a carbon-nanotube-filled tank for storing hydrogen, a plastic tank for holding potassium hydroxide (KOH) and metal (e.g., zinc (Zn), other metals, and the like) particles, and the like), one or more sponges, one or more containers (e.g., a plastic

container for holding dry metal (e.g., zinc (Zn), other metals, and the like) particles, and the like), one or more vats, one or more barrels, one or more vessels, and the like, and suitable combinations of any two or more thereof. Optionally, the fuel storage unit 108 is detachably attached to the system.

The optional second reactant storage unit 110 comprises a unit that can store the second reactant. Exemplary second reactant storage units include without limitation one or more tanks (for example, without limitation, a high-pressure tank for gaseous second reactant (e.g., oxygen gas), a cryogenic tank for liquid second reactant (e.g., liquid oxygen) which is a gas at operating temperature (e.g., room temperature), a tank for a second reactant which is a liquid or solid at operating temperature (e.g., room temperature), and the like), one or more sponges, one or more containers, one or more vats, one or more barrels, one or more vessels, and the like, and suitable combinations of any two or more thereof. Optionally, the second reactant storage unit 110 (if present) is detachably attached to the system.

In one optional embodiment, the volumes of one or both of the fuel storage unit 108 and the optional second reactant storage unit 110 can be independently changed as required to independently vary the energy of the system from its power, in view of the requirements of the system. Suitable such volumes can be calculated by those of skill in the art utilizing, among other factors, the energy density of the system, the energy requirements of the one or more loads of the system, and the time requirements for the one or more loads of the system. In one embodiment, these volumes can vary in the range(s) from about 0.001 liters to about 1,000,000 liters.

In one embodiment, at least one of, and optionally all of, the metal fuel cell(s) is a zinc fuel cell in which the fuel is in the form of fluid borne zinc particles immersed in a potassium hydroxide (KOH) electrolytic reaction solution, and the anodes within the cell cavities are particulate anodes formed of the zinc particles. In this embodiment, the reaction products can be the zincate ion, $Zn(OH)_4^{2-}$, or zinc oxide, ZnO, and the one or more second reactants can be an oxidant (for example, oxygen (taken alone, or in any organic or aqueous (e.g., water-containing) fluid (for example and without limitation, liquid or gas (e.g., air)), hydrogen peroxide, and the like, and suitable combinations of

any two or more thereof). When the second reactant is oxygen, the oxygen can be provided from the ambient air, or from the second reactant storage unit 110. Similarly, when the second reactant is oxygen in water, the water can be provided from the second reactant storage unit 110, or from some other source, e.g., tap water.

In this embodiment, the particulate anodes are gradually consumed through electrochemical dissolution. In order to replenish the anodes, to deliver KOH to the anodes, and to facilitate ion exchange between the anodes and cathodes, a recirculating flow of the fuel borne zinc particles can be maintained through the cell cavities. This flow can be maintained through one or more pumps (not shown) or through some other means. As the potassium hydroxide contacts the zinc anodes, the following reaction takes place at the anodes:

$$Zn + 4OH^- \rightarrow Zn(OH)_4^{2-} + 2e^- \qquad (1)$$

The two released electrons flow through a load to the cathode where the following reaction takes place:

$$\frac{1}{2}O_2 + 2e^- + H_2O \rightarrow 2OH^- \qquad (2)$$

The reaction product is the zincate ion, $Zn(OH)_4^{2-}$, which is soluble in the reaction solution KOH. The overall reaction which occurs in the cell cavities is the combination of the two reactions (1) and (2). This combined reaction can be expressed as follows:

$$Zn + 2OH^- + \frac{1}{2}O_2 + H_2O \rightarrow Zn(OH)_4^{2-} \qquad (3)$$

Alternatively, the zincate ion, $Zn(OH)_4^{2-}$, can be allowed to precipitate to zinc oxide, ZnO, a second reaction product, in accordance with the following reaction:

$$Zn(OH)_4^{2-} \rightarrow ZnO + H_2O + 2OH^- \qquad (4)$$

In this case, the overall reaction which occurs in the cell cavities is the combination of the three reactions (1), (2), and (4). This overall reaction can be expressed as follows:

$$Zn + \frac{1}{2}O_2 \rightarrow ZnO \qquad (5)$$

Under real world conditions, the reactions (4) or (5) yield an open-circuit voltage potential of about 1.4V. For additional information on this embodiment of a zinc

battery, the reader is referred to U.S. Patent Nos. 5,952,117; 6,153,329; and 6,162,555, which are hereby incorporated by reference herein as though set forth in full.

The reaction product $Zn(OH)_4^{2-}$, and also possibly ZnO, can be provided to reaction product storage unit 104 (if present). Optional regeneration unit 106 can then reprocess these reaction products to yield oxygen, which can be released to the ambient air or stored in second reactant storage unit 110, and zinc particles, which are provided to fuel storage unit 108. In addition, the optional regeneration unit 106 can yield water, which can be discharged through a drain or stored in second reactant storage unit 110. It can also regenerate hydroxide, OH^-, which can be discharged or combined with potassium to yield the potassium hydroxide reaction solution.

The regeneration of the zincate ion, $Zn(OH)_4^{2-}$, into zinc and one or more second reactants, can occur according to the following overall reaction:

$$Zn(OH)_4^{2-} \rightarrow Zn + 2OH^- + H_2O + \frac{1}{2}O_2 \qquad (6)$$

The regeneration of zinc oxide, ZnO, into zinc and one or more second reactants can occur according to the following overall reaction:

$$ZnO \rightarrow Zn + \frac{1}{2}O_2 \qquad (7)$$

Compared to hydrogen fuel cells, metal fuel cells are typically more suitable for an office environment because the fuel involved, metal particles or fluid born metal particles in an electrolytic reaction solution, is generally inert, and neither explosive nor flammable. Thus, the invention system, comprising metal fuel cells, optionally can be configured to not utilize or produce significant quantities of flammable fuel or product, respectively. Moreover, the invention system, comprising metal fuel cells and unlike systems comprising hydrogen fuel cells, optionally can be configured to expel substantially no reaction product(s) outside of the system (e.g., into the environment). Further, the invention system, comprising metal fuel cells, unlike systems comprising hydrogen fuel cells, does not require high pressure to store the fuel, and optionally can be characterized by a fuel storage unit that can store fuel at an internal pressure in the range(s) from about – 5 pounds per square inch (psi) gauge pressure to about 200 psi

gauge pressure. Moreover, unlike hydrogen, this fuel is also generally more compact for a given energy output. Thus, the invention system, comprising metal fuel cells, optionally can be characterized by an energy density in the range(s) from about 35 Watt-hours per kilogram of combined fuel and electrolyte added to the system to about 400 Watt-hours per kilogram of combined fuel and electrolyte added to the system. Further, the invention system, comprising metal fuel cells, optionally can further comprise an energy requirement and can be configured such that the combined volume of fuel and electrolyte added to the system is in the range(s) from about 0.0028 L per Watt-hour of the system's energy requirement to about 0.025 L per Watt-hour of the system's energy requirement. This energy requirement can be calculated in view of, among other factors, the energy requirement(s) of the one or more load(s) comprising the system. In one embodiment, the energy requirement of the system can be in the range(s) from about 50 Watt-hours to about 50,000 Watt-hours. In another embodiment, the energy requirement of the system can be in the range(s) from about 5 Watt-hours to about 50,000,000 Watt-hours. Therefore, the metal fuel cell has significant advantages compared to the hydrogen fuel cell in terms of providing backup power to one or more loads.

An advantage of fuel cells relative to traditional power sources such as lead acid batteries is that they can provide longer term backup power more efficiently and compactly. This advantage stems from the ability to continuously refuel the fuel cells using fuel stored with the fuel cell, from some other source, and/or regenerated from reaction products by the regeneration unit. In the case of the zinc fuel cell, for example, the duration of time over which energy can be provided is limited only by the amount of fuel which is initially provided in the fuel storage unit, which is fed into the system during replacement of a fuel storage unit, and/or which can be regenerated from the reaction products that are produced. Thus, the system, comprising at least one fuel cell that comprises a regeneration unit and/or a replaceable fuel storage unit, can provide backup power to the one or more loads for a time in the range(s) from about 0.01 hours to about 10,000 hours, or even more. In one aspect of this embodiment, the system can provide back-up power to the one or more loads for a time in the range(s) from about 0.5 hours to about 650 hours, or even more.

Finally, it should be appreciated that embodiments of metal fuel cells other than zinc fuel cells or the particular form of zinc fuel cell described above are possible for use in a system according to the invention. For example, aluminum fuel cells, lithium fuel cells, magnesium fuel cells, iron fuel cells, and the like are possible, as are metal fuel cells where the fuel is not in particulate form but in another form such as sheets or ribbons or strings or slabs or plates. Embodiments are also possible in which the fuel is not fluid borne or continuously recirculated through the cell cavities (e.g., porous plates of fuel, ribbons of fuel being cycled past a reaction zone, and the like). It is also possible to avoid an electrolytic reaction solution altogether or at least employ reaction solutions besides potassium hydroxide, for example, without limitation, sodium hydroxide, inorganic alkalis, alkali or alkaline earth metal hydroxides. See, for example, U.S. Patent No. 5,958,210, the entire contents of which are incorporated herein by this reference. It is also possible to employ metal fuel cells that output AC power rather than DC power using an inverter, a voltage converter, and the like.

Embodiments of Systems According to the Invention

Referring to Figure 2, an embodiment 200 of a system according to the invention comprises one or more metal fuel cells 100 for providing backup power to one or more loads 206 upon the occurrence of a power outage condition, defined to include a disruption or discontinuation in the delivery of primary power (i.e., power from the primary source 208) to one or more loads 206. A further component comprising the system, a controller 202, senses the power outage condition and, responsive thereto, operatively engages the one or more metal fuel cells 100 to provide power (i.e., backup power) to the one or more loads 206. When there is a resumption of primary power to the one or more loads 206, the controller 202 optionally can be configured to sense this condition, and disengages the one or more fuel cells 100 from powering the one or more loads 206. Optionally the controller 202 sensing the resumption of delivery of primary power to the one or more loads 206 then engages the primary power to provide power to the one or more regeneration units in the one or more fuel cells 100 so as to regenerate the reaction products stored in the fuel cells 100 back into fuel for reuse. Further, the

controller 202 optionally can be configured to engage flow of the one or more second reactants into the power source 102 responsive to sensing the outage of primary power to the one or more loads 206. Suitable controllers include without limitation human operator(s), mechanical sensing device(s), computer-operated sensing device(s), robotic sensing device(s), electrical sensing device(s), solid state electronic switch(es), electromechanical switch(es), and the like, and suitable combinations of any two or more thereof.

An optional power conversion unit 204 can also be provided as a component of the system, depending on the nature and characteristics of the one or more loads 206, and the one or more metal fuel cells 100. The optional power conversion unit 204 comprises a unit that can convert power from one form (e.g., direct current, or DC, form; alternating current, or AC, form; and the like) to another form. Exemplary power conversion units 204 include one or more voltage converter(s), one or more inverter(s), one or more DC to DC converter(s), and the like, and suitable combinations of any two or more thereof. The optional power conversion unit 204 functions to convert the power output from the fuel cell to another form or, optionally, in the case of supply of power from the primary source to the regeneration unit, power from the primary source to another form for regeneration purposes. In one embodiment, the optional power conversion unit 204 operates to convert the DC power provided by the one or more fuel cells 100 to AC power. In another embodiment, the optional power conversion unit 204 operates to convert the DC power provided by the one or more fuel cells 100 to another form of DC power.

Referring to Figure 3, an implementation 300 of a system according to the invention includes a means 302, as described above, for physically supporting the one or more fuel cells 100, optionally the controller 202, optionally the optional power conversion unit 204, and at least one of the one or more loads 206a, 206b, optionally in an integral fashion. Alternatively, the fuel cells 100, controller 202, and the optional power conversion unit 204 can be packaged together within a means for physically supporting them, optionally in an integral fashion, and mounted separately from the loads 206a and 206b. Such means for supporting include, without limitation, one or

more rack(s), one or more shelf(ves), one or more stands, one or more tables, one or more apparatus that can support one or more components of the system of the invention, and the like, and suitable combinations of any two or more thereof.

Figure 4 is a flowchart of an embodiment 400 of a method of operating a system according to the invention. The method is performed upon the occurrence of a power outage condition, and begins with step 402, in which the power outage condition is sensed. The method then proceeds to step 404, in which, upon (e.g., at or after, or the like) the time of the sensing of a power outage condition, one or more metal fuel cells are operatively engaged to provide power to one or more loads. Optional step 406 can also be performed during this time of operative engagement. In optional step 406, depending on the nature and characteristics of the one or more fuel cells and the one or more loads, the power from the one or more fuel cells can be converted to another form. In one example, the power from the one or more fuels is in the form of DC power, and this step converts the DC power into AC power.

The one or more fuel cells can continue to provide power to the one or more loads for the substantial duration of the power outage condition. At some point, the power outage condition ceases and delivery of primary power to the loads is resumed. In step 408, this event is sensed, and, upon the time of sensing this event, step 410 is performed. In step 410, the one or more metal fuel cells are operatively disengaged from providing power to the one or more loads. In optional step 412, the primary power is operatively engaged to provide power to the one or more regeneration units within the fuel cells 100 so as to regenerate the reaction products stored in the fuel cells 100 back into fuel for reuse.

In a further embodiment, the invention provides methods of pre-charging a fuel cell system for providing backup power to one or more loads. Such methods comprise placing an amount of fuel in cell cavities of a power source of a fuel cell system prior to operative engagement of the fuel cell system. This amount of fuel can be sufficient to operatively engage the fuel cell system for a time in the range(s) from about 0.001 minutes to about 100 minutes without additional fuel being added thereto. Optionally, the fuel is kept in the cell cavities for a time prior to operative engagement

of the fuel cell system in the range(s) from about 0.001 minutes to about 10 years or more.

In another embodiment, the invention provides methods of utilizing a precharged fuel cell system for providing backup power to one or more loads. Such methods comprise operatively engaging a fuel cell system, containing fuel in cell cavities of a power source of the fuel cell system prior to its operative engagement, for a time in the range(s) from about 0.001 minutes to about 100 minutes without adding additional fuel thereto.

As utilized herein, the term "about" comprises any deviation upward or downward from the value modified by "about" by up to 20% of such value.

As employed herein, the term "in the range(s)" comprises the range defined by the values listed after the term "in the range(s)", as well as any and all subranges contained within such range, where each such subrange is defined as having as a first endpoint any value in such range, and as a second endpoint any value in such range that is greater than the first endpoint and that is in such range.

As utilized herein, the term "significantly faster" comprises any increase in the time value modified by "significantly faster" that is in the range(s) greater than 10% of such time value.

While various embodiments of the invention have been described, it will be apparent to those of ordinary skill in the art that many more embodiments and implementations are possible that are within the scope of this invention.